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ABSTRACT

In order to build a framework in which to discuss the evolution of data communications, the three main components of a basic data transmission system (source, medium and data sink) are considered to see what has happened in each area since 1960. This somewhat oversimplified basic approach is taken in order to avoid the confusing terminology and jargon which seem to haunt this field. The source can be any data source, including a computer system, which is transmitting data through a medium to a data sink. The medium is everything between the source and sink. The sink is often assumed to be a computer system but this is not necessarily true, since it can be a paper tape, punched cards or a central processor. The evolution of each of these three basic elements within the 10-year time frame is discussed in detail in the most elementary terms and graphically shown by figures and diagrams. A short glossary of data communications terminology is appended. (NH)

DATA COMMUNICATIONS - A CONTINUING EVOLUTION

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by

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DATA COMMUNICATIONS - A CONTINUING EVOLUTION

I. INTRODUCTION

"Never before has a marriage been consummated in a technological field that has had such a critical period of adjustment as the union of computers and data transmission."

I am quoting from a publication that was written some 3 or 4 years ago, but nothing indicates that it is no longer true.

What are the characteristics of this area that Auerbach has described as a crack between two technologies?

If the technical and people problems added to the regulatory and cost considerations were not enough, the growth of data communications alone would be enough to create problems.

Let us look briefly at this growth.

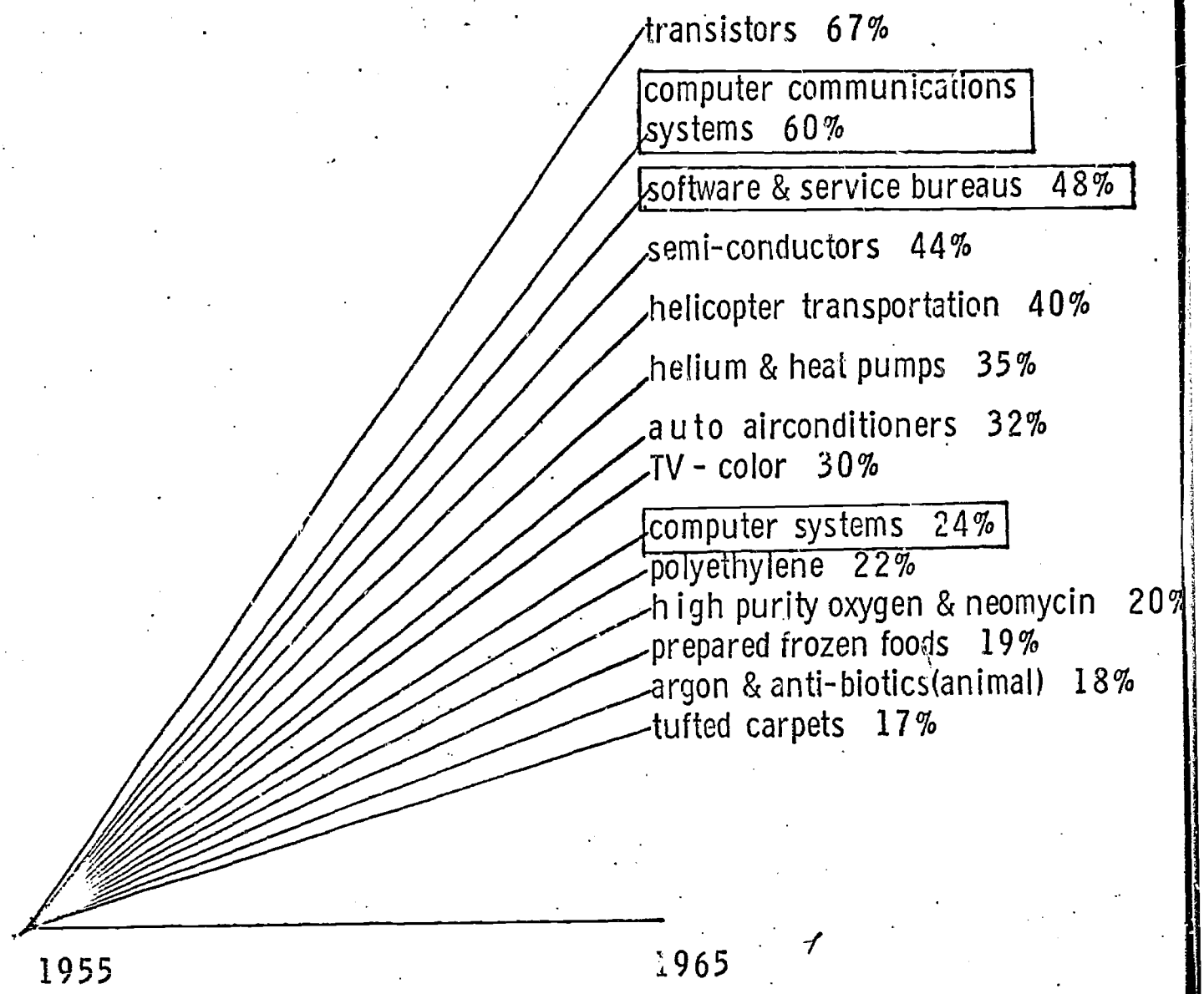
First the average annual growth rate over a ten year period compared to other sectors of the economy is shown in Figure 1. Especially interesting is the comparison with computer systems having no communications.

A BEMA Industry study in 1967 showed little change in this growth rate - from 1960 to 1966 the 60% figure was still maintained based on the value of installed systems.

Of course, in terms of total installed value, non-communication computer systems still have a large lead, although an increase from 12% to 50% in remote computing is predicted within 3-5 years.

Another way of looking at data communications growth is by examining the remote terminals and the data sets or modems which are used to interface the terminal or computer to the transmission medium.

AVERAGE ANNUAL RATE OF GROWTH



Sources:

U.S. Dept. of Commerce; Office of Business Economics;
Business Equipment Manufacturers Association;
Computers and Automation.

FIGURE 1

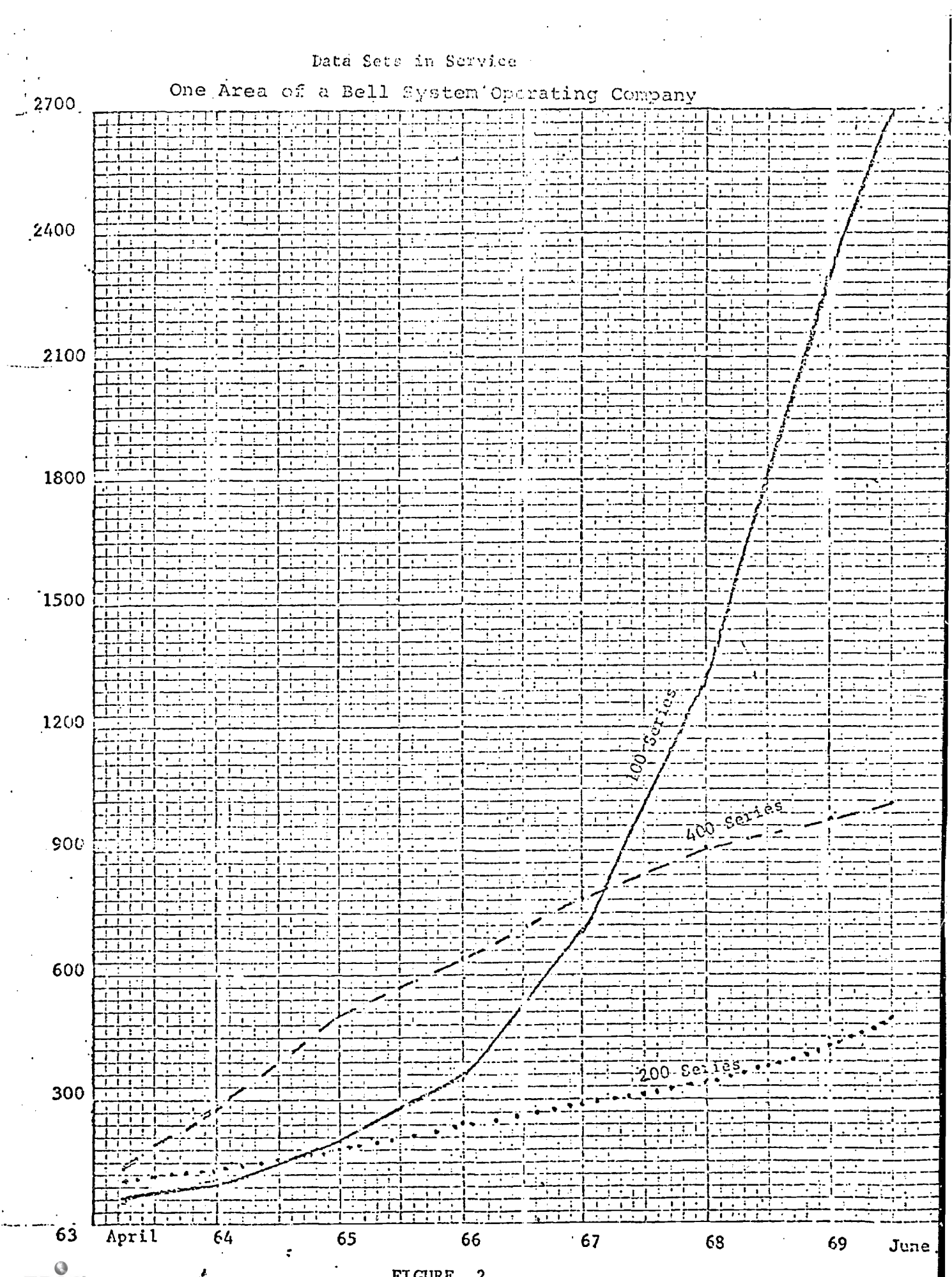

Data Sets in Service
One Area of a Bell System Operating Company
2700
2400
2100
1800
1500
1200
900
600
300
63
April
64
65
66
67
68
69
June
100 Series
400 Series
200 Series

FIGURE 2

Data set production between 1963 and 1965 was compared in one industry study and showed an annual growth rate of 58%. Terminal inventory in the computer industry i.e., the number of installed terminals, was compared between December 1963, and December 1966, and showed a 47% growth rate. These last two figures were from the U.S. Dept. of Commerce Industrial Reports and the BEMA survey in 1967. Of course, more recent forecasts have shown some phenomenal growth trends in remote terminals - up several hundred percent in three years by some authorities. However, it is useful to look at the figures in retrospect. In this connection Figure 2 shows the data set growth in one area of a local telephone company. The significant thing in these curves is the 100 series. These are the data sets that operate with the low speed devices - teletype, IBM 2741, Friden, etc. - in other words time-sharing terminals. If the effect of acoustic couplers is considered (starting approximately two years ago), which compete directly with the 100 series data sets, the time sharing growth can really be appreciated.

When did data communications as a separate entity begin and, for that matter, what is it?

The Bell System used a definition five or six years ago in one of their introductory texts on the subject, which is useful as it eliminates philosophical transmission systems such as a truck carrying punched cards that contain data. This definition of data communications states it as "The movement of encoded information by means of electrical transmission systems."

Information or meaningful data is specified in the definition, the encoding process is assumed, and the term electrical eliminates some forms of transmission but certainly includes the new developments such as laser beams.

Although data communications in basic teletype form has been with us longer than computer technology, it followed computers by several years when data sets and sophisticated terminals such as CRT devices are considered; computers with communications capabilities are also a more recent development.

One indication of its birthdate might be the report published by the Bell System in 1960 entitled "Capabilities of the Telephone Network for Data Transmission". This report was the culmination of a series of tests undertaken by the Bell System in 1958, which showed that it was practical to use the telephone switched network for data transmission, with some limitations because of error

rates. These error rates have been quoted widely and in come cases out of context. We will refer to them later. Before those tests it was purely guesswork that the existing telephone plant could be used for data transmission.

In order to have a framework in which to discuss the evolution of data communications, I would like to consider the three main components of a basic data transmission system and see what has happened in each area since 1960. Let us look at the basic system. (Figure 3)

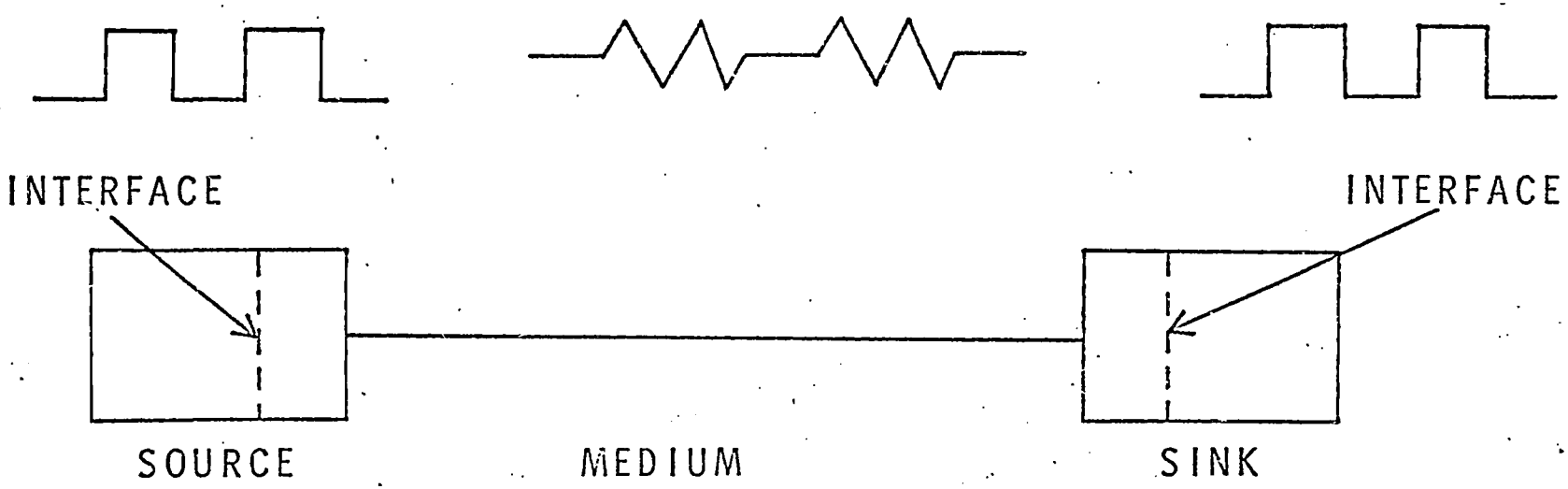
Although this may seem somewhat oversimplified it is important to take this basic approach in order to avoid the confusing terminology and jargon which seems to haunt this field. The source, for example, allows us to think in terms of any data source, including a computer system, which is transmitting data through a medium to a data sink. A variety of terms can be dispensed with by using the term source - encoder, transmitter, remote terminal, etc. The dotted line labeled interface suggests that the data source consists of two distinct parts; one of which is doing the actual interfacing, (or coupling) to the transmission medium. This, in turn, suggests that some process must occur at this point before the data can enter the medium.

The medium can be as simple as a few feet of wire between two devices, or as complex as a microwave system between Alaska and California. This means that in studying errors in data transmission, with their causes and cures, we must consider everything between the source and sink as part of the medium; therefore, a potential problem area. This includes any telephone company central office switching equipment, any channel multiplexing equipment, any repeater amplifiers, and the cables and wires which complete the path.

The sink is often assumed to be a computer system. This is not necessarily true, and again the basic system should be kept in mind. An off-line system may be the arrangement under consideration, e.g.; two magnetic tape transmission units operating together over telephone lines.

Another point to keep in mind is that the source and sink in a system may be constantly changing places. In an inquiry-response application, the source (in this case a remote terminal device), sends an inquiry to the sink (in this case a central processor). The response to this inquiry now makes the CPU the source and the remote terminal the sink.

BASIC DATA TRANSMISSION SYSTEM



PROBLEMS:

MODULATION REQUIREMENT
ENERGY LOSS
TIME DELAY

FIGURE 3

The changes in these three components - source, medium and sink, will now be considered in the ten year timeframe, and with an eye to future trends.

II. THE DATA SINK

First we will begin with the data sink.

As mentioned earlier, the sink is not necessarily a computer and in the early days, of course, it was definitely not a processor. We had teletypewriters providing us with paper tape which we could then feed to a paper tape reader on the computer, and we had a key punch with a translator which allowed us to receive punched cards over telephone lines, again for insertion into a reading device on the CPU. Other higher speed paper tape systems appeared such as Digitronics, Tally and Bell's Dataspeed II. Terminals which could send and receive magnetic tape made their appearance, and in the high speed card transmission applications, IBM's 1013 terminal was available, also equipment from several other vendors.

These off-line systems had one advantage over on-line systems - no specialized software was required to service the remote terminals or data sources with interrupt handling, etc. Transmission errors presented problems but not to the same degree as with an on-line system which might have to be arranged to break the line connection if errors occur. With an off-line system, too, errors might be caught and corrected before the data was fed into the computer system.

However, the off-line systems had many disadvantages when the capabilities of an on-line computer system were used as the data sink. There is an analogy here to the use of jet planes with their faster speeds and increased services. Although the bulk of passenger traffic is handled by jets there are still many non-jets in service; in the same way there are still many off-line data transmission systems in service.

As second generation computers began to develop and be used in the early '60's, the evolution of on-line data transmission systems began. In many cases this was the addition of some type of communications controller to the existing product line. This controller was connected either to a selector channel on the central processing unit or a trunk of the multiplexing (or multiplexor) channel, sharing it with the slower speed devices such as card readers.

It is important to note that many second generation computer systems were not readily adaptable for on-line communications and off-line systems still continued to be used in many instances. With the variety of machine languages, code translation was a problem and there was little vendor supplied communications software. There were, however, noteable breakthroughs - it was in this era that message switching systems using computers for the store and forward element came into the spotlight. Worthy of mention is the military's AUTODIN system with its numerous switching centers and a traffic load of some 700 million characters a day. It was implemented using second generation computer equipment, and is still the largest message switching system in the world. Several of the first on-line airline reservation systems were also implemented in this time period.

As on-line systems progressed, some definite areas of application were identified. These are summarized on the table in Figure 4, which lists the classical application areas of communications and computers.

1. Data Collection

   This is usually taken to mean the factory oriented devices which read an employee badge or a punched card, and usually have some variable keys for manual entry. Time and attendance reporting is a typical application area. The term "data collection" has more general connotations, however, and the method by which the data is captured is not so important as the fact that it is transmitted to the computer on-line with little or no data returned to the point of origin. A computer system which automatically dials remote terminals and then receives their data is also a good example of data collection. To conserve costs, this dialing may be done using a WATS service either IN or OUT and the remote terminals may be unattended in the OUTWARD case. Processing may not always be done immediately as the data can be logged on magnetic tape after being received, and processing done at a later time. (This is sometimes referred to as an "off-line" system, even though some type of processor is used to receive the data.)

2. Data Dissemination

   This is the opposite of data collection and is sometimes combined with data collection in a particular system. Examples of pure data dissemination would include the APB network used in police systems where a broadcast type message is being sent to a number of stations, and a remote

DATA COMMUNICATIONS

MAIN APPLICATION AREAS:

1. Data Collection
2. Data Dissemination
3. Inquiry - Response
4. Message Switching
5. Time Sharing
   - A. Conversational
   - B. Computer Load Balancing
   - C. Remote Batch Processing

FIGURE 4

on-line printer receiving invoices or listings of some type. Trucking companies sending freight bills ahead of the transport to speed up deliveries, is a good example of this on-line printing.

3. Inquiry-Response

This is probably the most used application, and is growing rapidly with the advent of more data bases with a wide variety of information. Inquiry-response should not be confused with conversational time sharing which often uses the same type of remote terminal, and similar computer hardware. Credit card authorization, computer assisted instruction, library systems - these are all examples of inquiry-response.

A new term "direct data entry" is usually grouped under inquiry-response, even though the response may be a simple ACKnowledge or NACK (non-acknowledge), or perhaps an error notification message. Direct data entry is merely an extension of the file updating used in inquiry-response systems, and is replacing key punching and data entry on magnetic tape in some instances. In some systems, of course, direct data entry may be a form of data collection - the difference being what is done with the data after reception by the computer. Does it update a file or is it merely the processing of raw data for payroll purposes, etc.

4. Message Switching

This was the area mentioned earlier. There are many systems in use from the large systems using full duplex lines, to small systems using a few teletype grade lines with several terminals on each line. In some systems, message switching is merely an added function on a system which was provided for some other purpose such as inquiry response, or possibly ordinary batch processing. Future development in this area should bring in more of the smaller communications users. Software for this application has been a problem in the past as a general purpose message switching package usually needs some modification for a particular customer. For example, messages with a certain error rate may be stopped before being completely received, or received in full with later notification to the sender of the errors. Priority schemes will vary widely, also message header validation schemes.

5. Time Sharing

This has become the area of greatest interest in the past few months and can really be broken into three distinct sub-headings:

(a) Conversational

This is the time-sharing area which is perhaps the best known, and is the one which appears to hold the greatest promise for the non-trained user, e.g. the executive with the terminal in his office. Program preparation is another large user area which has not been exploited to any extent as yet. In the conversational mode the computer executes commands given by the user at the terminal, in effect a "dialog" between the user and the computer.

Engineering and scientific applications usually led to the use of time sharing bureaus by many companies, and the evaluation must now be made on these facilities compared to an in-house computer system for this and other time sharing functions.

(b) Computer Load Balancing

In some texts, this is given a separate heading, and is not listed under time sharing. One computer is the host and the other the slave, acting under direction of the host.

(c) Remote Batch Processing (Sometimes referred to as Remote Job Entry)

This is a rapidly growing phase of time sharing and is usually characterized by a remote-card reader (with or without a punch), and an on-line printer. This printer/reader combination is fast in the communications sense - reading cards at 200-400 cpm and printing at 200-300 lpm. In practice, however, their speeds are data set and line limited. With the newer high speed modems which are beginning to appear at 4800 and 9600 bits per second, we will finally begin to obtain the full capability of these devices. Small satellite computers could also be used for remote batch proces-

sing, where the satellite might do some validation and minor formatting, and also concentrate the lines from slow speed remote terminals into one higher speed line which connects to the central location. Some of these satellite processors may also provide local reports.

Some companies which use service bureaus have, of course, been doing a form of remote batch processing using paper tape, but this has been at low speeds, e.g. teletype, and for low volume applications.

With the advent of third generation computer hardware cam an enhanced capability in the communications controller, i.e. the front end device which buffers the CPU from the conglomerate and rapidly changing world of remote terminals. Some of these controllers are very flexible and do many things which the CPU had to do with software in earlier systems, e.g., character and block parity checks, hardware translation or the line transmission codes, special character recognition, and the addition or stripping of start/stop bits in asynchronous systems. Communications controllers are of two main types - single channel for handling high speed transmission(such as computer to computer)using TELPAK, or similar broadband facilities, (the telephone company calls it wideband); and the multi-channel type which can often handle a number of different transmission speeds, different line transmission codes, and different synchronization modes.

Also with third generation systems has come improved vendor software for communications. As some of you know, there is still much room to grow in this area. When new terminals are introduced the existing software should be flexible enough to handle most of them, and with minor modifications so should the hardware. In many cases, vendor evaluation procedures are slow, and the user does not know whether or not to use the terminal he has chosen. Computer to computer interfaces involving more than one vendor have been a particularly sensitive area. USASCII standardization definitely has been of assistance in attacking the problem.

The most recent development in the use of a computer as a data sink is the introduction of a number of small processors or so-called

"mini-computers", which can be used in a communications environment either as front-end processors or as remote satellites.

These units can do limited processing or pre-processing which can include validation routines of message formats, line code and line speed conversion, some forms of message switching, tape logging, local report printing, various forms of error checking, etc. In addition, this can be a convenient method of concentrating a number of low speed lines into one voice grade line which connects the small computer to the centralized processor location, thus saving line costs. For the concentrator function the choice is between a hard wired multiplexor (which we will mention later), or a small processor. The latter has the processing advantages mentioned, but is generally more expensive.

With the growth of large networks using centralized data banks, the increased use of small processors for communications uses seems certain. In fact, the functional separation between the larger communication controllers and the smaller front-end processors is rapidly growing smaller.

Economics also favor the small computer for companies who are not too sure they can afford communications on a computer. The only adverse note appears to be in the software area. With a small purchase price the vendor will be unable to supply much sophistication in communications software.

My frame of reference here, incidentally, is $2,500 per month or less, including peripherals.
I am aware, of course, that some of these smaller processors for specialized uses can go up to double this cost and files for local inquiries may be available on peripheral equipment.

III THE MEDIUM

The available transmission media for data communications break down into the two general categories of public facilities (provided by the common carrier), and privately owned facilities (not to be confused with private line service from the telephone companies). Except for a sudden increase in the use of private microwave during the early 1960's (e.g., several oil companies have their own networks), which was met by the introduction of the Bell System's

TELPAK service, (a cheaper by the dozen approach to private line facilities), there has not been any marked increase in the use of private facilities for carrying data. Frequency allocation for microwave is still a problem area. In fact, one company in the past few months which has a requirement for data transmission has applied to the FCC for licensing as a common carrier, obviously to sell the excess capacity of this new network to other users.

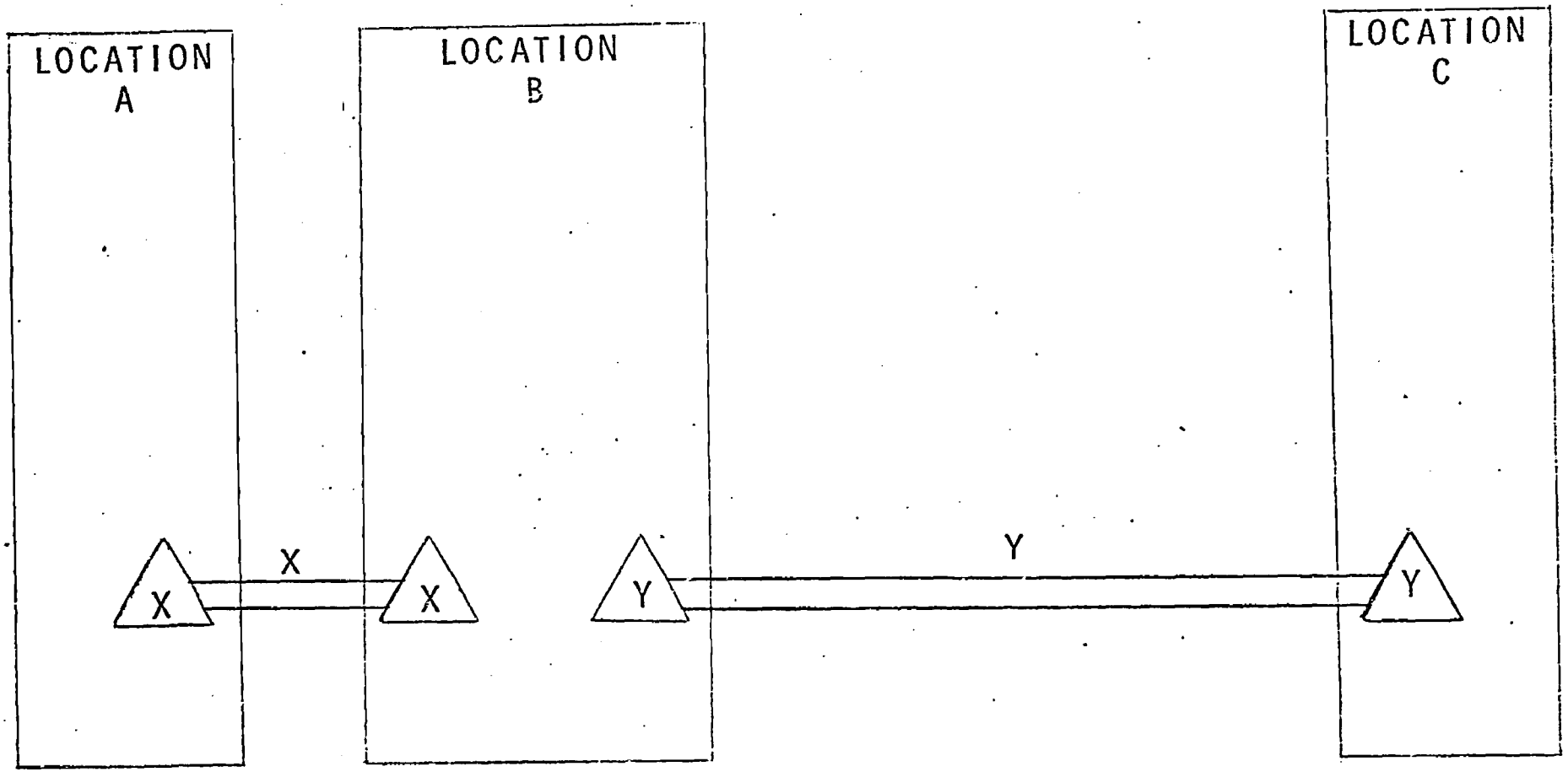
This situation may not persist in the future. There are indications that business groups with the same community of interest may attempt to provide domestic satellites to serve their communication needs. Of course, there is a problem of convincing the regulatory agencies that this is in the public interest. They may take the view that A.T.&T. should allow the shared use of TELPAK for these user groupings, which is only done for regulated industries at present, e.g., trucking companies.

Under private service, of course, many companies use their own switchboard systems, which can be used alternately for some of the lower speed data traffic. In-house data collection systems are also often cabled to a computer using privately owned line facilities.

Under common carriers we have both foreign and domestic. There are six overseas carriers at present, the three largest being ITT, RCA GLOBAL Communications, and W. U. International. They have greatly increased their data handling capacities and their service offerings in the past ten years, although record traffic of the Telex variety, plus voice, is still the major part of their business. For many years only telegraph cables were available on an international basis. In the late fifties, the first trans-Atlantic telephone cable was laid, and there has been a steady increase in this service in the subsequent years. Several cables are now available between the U.S. and both Europe and the Orient - which includes Japan, Australia, the Phillipines and Honolulu. In the past four or five years, international satellites have entered the picture, and the overseas carriers use many channels from this medium for their customers.

When domestic common carriers are considered one immediately thinks of the A.T.&T. and its associated companies, which are known as the Bell System. However, there are still over 2,000 independent telephone companies in the U.S., some of them very small, but including the very large General Telephone. This fact can be important when providing a data transmission medium between two locations, which are in territories served by different telephone companies. Although most of them try and provide compatible services, rates on items such as

AN AEROSPACE COMPANY



X - INDEPENDENT TELEPHONE COMPANY RATES

Y - BELL SYSTEM RATES

data sets can vary considerably, and lead times on providing service will vary appreciably from one location to another.

One example is an aerospace company in the L.A. area. It has 3 main locations which are all in the territory of an independent telephone company. There is a need for data transmission between these locations and for two of them this involves only the independent telephone company. However, for the third location the line facilities of a Bell System operating company are involved. Thus, the data sets in one location have two different monthly rates depending on whether or not they are connected to Bell System lines. The line rates, of course, are also different. When end-to-end testing is required for maintenance reasons, personnel of two different telephone companies are involved, and as we all know human communication is often the biggest problem area in a communications system.

What changes in data communications services have the common carriers made in the past ten years?

Many of these services, such as Wide Area Telephone Service, were really designed for voice service or had a dual role; however, they have proved very useful for many businesses that use data transmission services.

Western Union completed a transcontinental microwave system and have added a number of new services in the past few years, e.g. Infocom Service allows a user to have a computerized message switching service, without having a computer in-house. W. U. provides the teletypewriter terminals, the lines, and the computer at its own location. Another Western Union offering, Broadband Exchange Service, is designed for the user who needs broadband facilities for high speed data but who pays on a time and distance basis (like long distance service), rather than a flat monthly rate which he would do for TELPAK from the telephone companies.

In a relatively short timeframe during the past ten years - approximately three years in fact, the Bell System introduced many new services which have become well known. Some of them have had some refinements since - such as providing for Inward WATS service in addition to the original Outward service - but at the time they were important milestones for the user. Dataphone® service provided for various types of data transmission over the public telephone network. This was limited to voice band speeds (2000 bps initially on the dialed network), but these speeds are beginning to increase through the design and development of

® Service mark of the Bell System

more sophisticated modulation and coding techniques. To summarize this concentration of new service offerings we can say that TELPAK, WATS, DATAPHONE®, the use of eight level ASCII coded teletype machines on the TWX network, DATASPEED® paper tape service, and the use of TOUCH TONE® card dialers for data entry: all appeared in the 1961-63 era.

To continue the evolution, we had tariff changes effective February 1, 1970, which reduced the rates for WATS and long distance calls out of state, but increased TELPAK and TWX charges. Note the trend to increase network or shared use as opposed to dedicated service.

One of the problems which has resulted from the growth of facility services is the user confusion when attempting to plan a data communications system. There are many cost tradeoffs and the system analyst must not only consider all the system factors when designing, but he should also be aware of what service offerings are available to him when the time comes to make a choice.

One example of the problems involved in optimizing costs is in WATS service I find that most people are aware that the zones of the country must be different depending on where the computer center is located, but they are not aware of the cost differences. A full time zone 6 WATS service from Dallas, Texas, which picks up New York City cost $1,950 per month prior to February 1. A Zone 5 from New York, however, which picks up Dallas cost $1,900 per month. Both INWARD and OUTWARD WATS rates are the same, so if only the two locations are involved a cost difference was available in the choice of serving location. Billing, of course, is to the center which provides the service, but this is usually an administrative problem that can be overcome.

Another pitfall to avoid is to provide a WATS service which encompasses the furthest location, although it has a small volume of traffic, and most of the calling is to a lower cost zone. This may be more costly than using straight long distance service to the furthest points, and a smaller numbered WATS zone for the other locations.

I referred to systems design and the need for taking all factors into account when designing and configuring a data communications system. There are seven classical design criteria which came from Bell System experience in the network area. They are still very much in use - in fact, a recent trade magazine had an article on data communications by a consultant who used most of these same parameters. I can only cover them briefly in the time available but are useful for another reason which is not usually mentioned - the selection ervice mark of the Bell System.

NETWORK DESIGN CRITERIA

FUNCTION

DISTRIBUTION

- One to One
- One to Many
- Many to One
- Many to Many

VOLUME

LANGUAGE

- Code
- Media

URGENCY

ACCURACY

COST

FIGURE 5

of remote terminals.(which we will discuss under the data source) Figure 5 lists these seven criteria.

1. Under Function we can list the system objectives which should be stated in terms of the company's own particular operations, and should consider future growth.

2. Distribution -
We must establish the most efficient pattern for moving the company's information. A geographical layout of all locations will assist in obtaining mileages for line costs, and will establish the calling pattern for the system. All distribution systems can be broken down into one or more of four basic patterns:

   (a) One point to one point
   - This is the pattern for inquiry response applications. The information flow can be in either direction alternately or simultaneously, or in one direction only i.e., half duplex, full duplex, or simplex.

   (b) One point to many other points. This is the pattern for data dissemination.

   (c) Many points to one point. The pattern for data collection.

   (d) Many points to many other points. This is the most complex pattern as every point in the system must be able to send and receive to every other point. We use this pattern in message switching.

3. Volume

This is the criterion which usually comes to mind even in the most basic system and much is involved here if the system analyst's job is to be done properly. Sample sizes, conversion of one unit to another e.g. words per minute to characters per second, the methods that can be used for carrying out traffic studies, and the derivation of the system usage in minutes for the peak or busy hour; all these are included.

4. Language

This covers two items (a) the physical form or medium of the information e.g. punched cards, hard copy, etc. and (b) the code to be used for encoding and/or transmitting the information.

5. Urgency

Some balance is necessary here to avoid costly high speed systems which bring in information before it is required for processing. On the other hand, late information is not worth the cost savings in the less expensive system that brings it to the processing center.

6. Accuracy

In recent years more realistic approaches are being taken in this area, as it is realized that human recording errors are a greater factor in the system than transmission errors. I referred earlier to the data transmission tests that were performed on the telephone network in 1958. The Bell System network plant has had many changes since that time, withremoval of open wire routes, and installation of microwave and the better types of central office equipment, i.e. crossbar and electronic offices. In addition, the tests were taken on all types of facilities, and with only one type of earlier data set. If you are in a metropolitan area with buried cable, or between two large cities on microwave, the error rates quoted in the Bell study (which were stated as a probability figure only), may be improved considerably.

These earlier study figures showed that for 80% of the calls at 600 bits per second the error rate would be 1 bit in every 100,000 bits transmitted or better, and at 1200 bits per second this would drop to about 70% of the data calls on the switched network having this error rate. With error detection and correction techniques, these figures can be greatly improved. Costs for this latter type of equipment are usually high, however, e.g. Dataspeed IV - a Bell System paper tape service, has monthly rates which are approximately double those for Dataspeed II which has no error detection capability. Dataspeed IV has three types of parity checking. When an error is detected the paper tape is pulled back at both the transmitter and receiver, and is overpunched at the receiver.

Dedicated facilities, i.e. private line services, have the advantage that they can be conditioned i.e. equalization techniques can be applied at each end of the channel to overcome the effects of line distortion. This conditioning, of course, is an extra cost item.

The systems analyst must really decide if an error will be catastrophic in his system. If he is involved in sending a man to the moon it could be. If, however, it can only result in a misspelled word, error detection is probably redundant. Between these two extremes lie a wide range of possibilities.

7. Cost

Total system costs should be evaluated not just equipment rental and line facility costs. If the remote terminals can operate in an unattended mode less personnel may be needed. What space will be occupied by the equipment you are choosing? Do the remote terminals require some special type of form? Several alternative systems should be costed before a decision is made.

Another area of medium change in the past two or three years, that has been accelerated by the time sharing growth, is the use of multiplexors to reduce line costs. The basic principle here is to concentrate a number of low speed channels, such as those used by teletypewriter devices - into one voice grade channel which can give us up to 9600 bps with the newer modems. Thus, we only pay for one voice grade channel from the point of concentration to the centralized computer site instead of a number of telegraph or sub-voice grade circuits (typically 12 to 18), with a consequent reduction in line costs. The individual low speed channels are separated in either frequency or time, and we have frequency division and time division multiplexors, both having tradeoffs. Time division multiplexors can handle digital signals (like pulse modulation devices), and make better use of bandwidth than frequency division multiplexors. They may not need demultiplexing equipment at the computer location, because software could be used to separate the data from the various channels. Either "bit" interleaving or "byte" (character) interleaving is done when the various low speed channels are separated in time by scanning. Time division techniques are used on the multiplexor channel of a computer which scans the various low speed devices (such as card readers), that are sharing the channel.

Frequency division multiplexors are generally less expensive for a small number of channels but the cost/channel curve is a straight line, and fairly steep when compared with time division multiplexors. The latter have a fairly large initial cost but then use much of the "common equipment" for the additional channels. Frequency division multiplexing has been used for many years by the telephone companies in their carrier equipment which puts 12 or more voice channels on one line. Another example is a home radio receiver which separates (by tuning), the various frequencies, which are all multiplexed at the receiving antenna.

Finally, under this discussion of the medium, which is the most controversial and the most difficult element to control in our basic system, let us look at some additional tariff items and their possible future effects.

The Carterfone case attracted much attention in 1968 because it dealt with foreign device attachments to the switched telephone network. A company in Dallas, Texas wished to attach a radio link to the network and was denied permission by the Bell System. In 1968, the FCC ruled that foreign devices could be attached to the switched network if proper precautions were taken to protect the other users of the network - which includes the millions of residence telephone users. It was anticipated then that many terminals and some computer hardware would have a built-in modulating and demodulating capa-

bility, and the modem or data set as a separate unit would disappear. This, however, has not appeared as a significant change as yet, although as you all know, it takes a considerable time for development before the marketing of a new device. Possibly changes will occur in the 4th generation of computers. Some terminals are advertising a built-in capability but on closer examination they are acoustic-coupled data sets with a dialing capability, and only the physical housing appears to be affected. Of course, even before the tariff changes, the provision of data sets or modems on a private line was left up to the user; and there was little or no talk of built-in modems for this purpose. Only a few modem vendors have announced switched network data sets since the tariff restrictions have been eased and as of the date of this paper only two have announced the built-in modulating capability.

In the area of data sets and modems the systems designer should be sure that if he is mixing Bell data sets and non-Bell data sets that they are compatible. He should also ensure that his computer and terminal equipment are compatible with the data sets he is going to use. The EIA RS232B interface specification was not specific enough in some areas, such as the voltage rise time on relay elements, and the newer modems with solid state circuitry may not always be compatible with earlier computer and terminal hardware. Maintenance considerations on data sets are very important when selecting a vendor, especially when they will be installed in remote areas.

Finally, under data sets, the user should be aware of the chronic shortages which keep appearing in the Bell data set stocks. Last year when time sharing was growing rapidly the low speed 103 type was in short supply, and still is in some areas. Now the telephone companies are quoting 8 to 12 weeks on the 200 series, which are used for CRT devices, remote printers and the like. Forecasting apparently is not very exact in this area.

How are costs evolving in this part of the data transmission system? Most users would probably say not very well. It must be remembered that one means of transmitting data is the switched telephone network and long distance rates have been coming down over the years, at the same time as some alternative means--U.S. mail, telegrams and express, have had rate increases. I mentioned the recent reduction in WATS rates earlier.

A trend of more bits for the dollar because of higher speed modems, multiplexors, etc. does not necessarily mean that communications costs as a percentage of the total system are reducing, as the terminal and computer cost curves are constantly changing.

Additional sources of data transmission facilities could help in this area of costs. Comapnies such as Microwave Communications Inc. have entered the field in some areas of the country, and although MCI now has FCC approval to offer service, a court case is pending with the A.T.&T. The whole question of rate structures between non-regulated and regulated companies, and between regulated companies who are only serving selected geographical areas and those who must serve a wide area, is a very complex one.

One Bell System speaker I heard recently mentioned that additional microwave networks between cities could only make the facility shortage in the cities worse. He was referring to the so-called local loops which run from the microwave terminal locations to the user's premises. These loops are usually provided in the form of underground or overhead cables, and, of course, the telephone companies provide virtually all of this service at present. The increased demand for service has cuased some serious problems - the classic case being the New York Telephone Company and the adverse publicity it has received in the past few months. Any time there are a large number of customers dialing into a time sharing computer center there must be a relatively large number of dial switches available in the telephone company central office, and a number of lines between the central office and the computer location. Although time sharing growth has been spectacular, one wonders whether the telephone company forecasting has been along traditional lines, or whether an ear was really turned to the marketplace for external stimuli. From the time forecasting is done it usually takes many months to get equipment and cable plant installed, using the telephone company cycles of engineering, manufacturing and installation. Although lessons have undoubtedly been learned from the experience at New York Telephone and other places, we might expect some additional facility problems in the short run before changes can be made. This will be especially true in other large centers like New York, where rapid time sharing growth will be a way of life for several years.

One figure which I saw the other day illustrates the growth problem faced by the telephone companies. It stated that the national telephone network had more than

doubled in the years 1963-68. This is impressive when one realizes that the telephone network was not tiny before 1963, and by a wide margin the largest network of its kind in the world. This type of growth rate would tax the resources of any organization - either regulated or non-regulated.

IV. THE SOURCE

When considering remote terminal evolution in the ten year period the various types of devices show definite "generations", similar to the computer groupings, but more related to functional capabilities than to the type of internal circuitry which is used. In fact, I often use this generation grouping in classes on data communications, for such items as teletype equipment, data collection equipment, card readers, CRT devices, etc.

In 1960, our teletype equipment was limited to the Model 28, which I think of as second generation, and the earlier 14, 15 and 19 type equipment. The 28 had a three row keyboard using the 5 level Baudot code with no parity checking capability, and was not very suitable for an on-line data transmission. These machines were very rugged and many are still in use for message switching systems; also for the slower speed TWX service at 60 words per minute.

When the next generation appeared in the early sixties we had the Model 33, which was a light duty machine, and the more rugged Model 35. Both of these machines had a 4 row keyboard, and the 8 level ASCII code. The customer had a choice of the eighth level being an even parity bit or always a one bit, (a hole in the paper tape). The equipment looked more like an office machine than the Model 28 but the width of the page copy was limited to the standard 8½" platen or the optional 9½" platen (which allowed approximately 84 characters to a line). Only capital letters were available on the keyboard, and the speed was still 10 characters per second, the same as the Model 28. In this era the Model 32 was also introduced. It is like the 33 in that it is a light duty device, but it has the 5 level Baudot code and a 3 row keyboard. It is used in Western Union's Telex service.

The Model 33 has been used widely for time sharing and inquiry-response applications and both the 33 and 35 are sometimes used as consoles in computer systems - usually with some additional electronics. In the past year or so there have been some chronic delivery delays due to the great demand for these machines, which are also used in TWX service at 100 words per minute.

Finally, we have the fourth generation (my own use of the term) with the Model 37. We now have upper and lower case letters and the two color ribbon is standard. The speed has increased to 15 characters per second, and we have features such as reverse line feed, back spacing on line, etc. The ASCII code used is the extended version (128 characters). The platen width is still the same, however, and could be a problem in some systems. There has been a long delay in obtaining these machines on a rental basis from the telephone companies, although they have been available from the Teletype Corp. on a purchase basis for some time.

This brings up one of the decisions which must be made when choosing terminals for a system - do we buy, rent or lease? Even though capital dollars may be more readily available than operating dollars, remember to consider maintenance. Who will do it? The telephone companies, and ususally the computer vendors, will not maintain equipment furnished by other companies. There has been an apparent lack of organizations in this field that provide a truly national service on various terminal equipment, including CRT devices. With the terminal growth which is forecast this has to be remedied. A natural growth of facilities management in the computer sense would appear to be in the network and remote terminal area, taking the problems away from the individual user and doing the job with skilled personnel.

Also, under maintenance, remember that multiple vendors in a system can often mean multiple maintenance problems, with the usual "finger-pointing" that occurs in these situations.

When considering either keyboard or paper tape terminals it is always useful to compare them with teletypewriter equipment both on features and cost. This illustrates one of the fundamentals in this terminal environment (where a new company seems to be born every hour), know several types of equipment well, and compare the new arrivals with them.

Before leaving teletype equipment there is one item I would like to mention in the time sharing area which could cause future problems to a user. It concerns the sale last year by the A.T.&T. of the TWX network to Western Union. This sale is planned for consummation in 1970. One of the terms and conditions of sale states that the A.T. & T. will not sell teletype service on a dial-up basis for five years after the TWX takeover by Western Union. At present virtually all of the teletypewriters used for time sharing service are on Dataphone service, i.e. they are using the ordinary switched network because of the rate advantages

over TWX service for short distances. In the future, then, the user will not be able to get his rental machine from the telephone companies (unless he already has at least one). He must purchase a teletype machine (with the resulting maintenance provision problems), or lease it from some other company. He then rents a data set from the telephone company to work with his teletypewriter.

There has been opposition to this provision of the TWX sale from some of the time sharing user groups, and if it is retained it could be another source of frustration to the potential time sharing user.

Again, I would like to make a suggestion, although I am not trying to launch new companies. Instead of having the user deal with a third party would it not be desireable if the time sharing service bureau also provided him with a terminal as an option, and arranged for the data set installation.

The evolution of teletype equipment has also been paralleled with other terminal equipment. Standardization has helped to overcome some of the computer hardware and software interface problems, but there is still much to be done. Although the ASCII code is present on virtually all new terminals, at least as an option, there are still various versions of BCD in the field. Buffered terminals have caused new problems in the software area. Terminal transmission speeds generally fall into several distinct categories, but there have been indications lately that this is changing as 20, 30 and 66 characters per second printers are being introduced.

Card transmitters began with the slow speed IBM 1001 - the type with a tray for the card - reading cards at a speed of 3 or 4 per minute. These evolved into several high speed readers at approximately 300 cards per minute -the IBM 1013 was one of them - and several low speed transmitters including the IBM 1050. Finally we now have several low speed card readers with flexibility in both speeds and the type of cards that are read. Two of them are made by Motorola and Hewlett-Packard. In the high speed field there are several card devices which usually form part of an on-line printer terminal, which I mentioned in connection with remote batch processing applications. Typical here are Univac's DCT 2000, the IBM 2780 and the RCA 70/740.

CRT terminals, or keyboard display devices as they are sometimes called, are a fairly new arrival in the terminal field. Large growth rates are predicted, although there

are less than 20,000 of the alphanumeric keyboard variety installed at present.

A problem with these devices has been cost, and some vendors are taking some unique approaches to overcome the problem. One of them is apparently taking the forecasts and deciding what the cost should be based mainly on the volume of sales.

There are several areas which should be examined more closely if cost reductions are to be made. One of these is transmission speed. There is always a tendency to follow the leader, and nearly all CRT terminals at present operate at either 1200 bits per second asynchronous or 2400 bits per second synchronous. If this was reduced to 300 bits per second a lower cost data set could be used. In many systems, this might be satisfactory, especially as the slowest element of the system is the operator assembling data on the screen in an off-line mode, at 2 to 3 characters per second.

Another item which needs to be examined is screen size. Many applications do not require anything larger than a 250-300 character screen, but most units on the market go up to 1000 characters, and some to 2000 characters.

Finally, the question should be asked, are all the features-such as three methods of erasing, really needed for all applications? I realize that market fragmentation is a problem, and making too many models will only increase costs. However, with the volumes presently forecast there is some scope in what can be done in future development. It should also be noted that these forecasts are based on reduced costs.

One development which will make a CRT unit more desireable is something better than a slow speed teletypewriter for providing hard copy. Several vendors have announced or will be announcing in the near future a printer which will copy a screen of data by scanning (using office copying techniques) for less than $200 per month.

Finally, under the remote terminal as a data source, let us mention the selection of the proper type of terminal, and the particular terminal of that type for your system. The use of the design criteria we mentioned earlier under networks can be of great value here. Before considering specific hardware look at items such as Volume and Urgency. They immediately establish a range of equipment transmission speeds. When we look at the media required in our system under Language, we have qualified the selection even more. Before going to available terminals

and costs, we should also examine the Accuracy criteria, to see if the terminal needs error detection and/or correction capabilities. To summarize, it should be possible to construct a small flow chart, with decision boxes that lead to several specific terminals, in a number of different categories. Only after this stage should particular vendor proposals be considered.

Remote terminals really fall into two broad categories not related to the media capability such as hard copy or paper tape. These two categories are the stand-alone units, and the controller type terminals. The stand-alone units interface directly to the data set and line. Examples are the IBM 2741, the Model 35 teletypewriter, etc. The controller types have a control unit which interfaces the line, and a number of peripheral devices connected to the control unit - such as card reader, keyboard/printer, paper tape punch, etc. Examples are the IBM 1050 system and the newer 2770; also the CDC 200 terminal. This type of equipment has some flexibility in configuration but where a location only needs one element (such as a printer), the required control unit could result in a cost disadvantage.

V. CONCLUSION

We have covered briefly the evolution of the three basic data transmission system elements. One thing that we have not mentioned in all these elements is the people problem, i.e., the continuing shortage of trained personnel in the data communications field.

Very few colleges teach data communications as a separate entity as yet, and I know of the interest in the subject from the size of my classes at UCLA. One of the most concentrated courses in this field, which is fairly well known, is the Bell System three month program at Cooperstown, New York. Although only intended for Bell System personnel it has been very beneficial for the industry, in fact there has been a very high attrition rate of the graduates. However, the current class is the last one at the school, which started in September 1961.

Two or three day data communication courses are given from time to time at some of the country's larger cities, by some computer vendors, and organizations such as the AMA. These, however, will not fill the need for some form of concentrated training over a period of time, which will stress practical applications. Where will this type of training come from?

I suggest that the telephone industry has a definite responsibility in this area. This does not have to be a free program but could be run on either a profit basis, such as other technical schools, or on a cost basis with good public relations as the goal.

In addition to increased training, the data processing industry has a responsibility to make its requirements known in this field, and make some organizational changes. There are too many instances of the data processing and communications groups reporting to different executives in a corporation, with much misunderstanding on how data communications should be implemented. A good start in this area would be some industry-wide job descriptions and functional titles. Any technology which has a 60% annual growth rate certainly deserves better definitions and goals.

With the so-called "unbundling" by computer vendors software houses will increase in number and scope so industry will get some assistance in the communications software area. However, even though there will be more trained personnel available than there were several years ago, there will be more demands on them, so the people shortages will persist.

Much is being written these days on the various aspects of data communications, some of it too specialized to be of help to the novice. Hopefully, better textbooks will be made available, and companies should have some individual in the training area sifting the available trade literature on data communications to disseminate to his own company. This will include not only the basics but current status on tariff changes, evaluation of new terminal equipment, descriptions of successful data communications installations, applications software and the like. In short, the users themselves will become part of the continuing evolution in data communications.

Data Communications Terminology

Asynchronous - Having a variable time interval between successive bits, characters or events. In data transmission, this is usually limited to a variable time interval between characters, and is known as start-stop transmission.

ASCII (USASCII) - American Standard Code for Information Interchange, usually pronounced "ASKEE". A standard data transmission code which was introduced to achieve compatibility between data devices. It consists of 7 information bits and one parity bit for error checking purposes, thus allowing transmission of up to 128 characters.

Baudot - A teletypewriter code with 5 bit characters, and no provision for error checking. Because of the inherent 32 bit capability, a shift character is necessary in order to transmit both figures and letters. Used on the Model 28 teletypewriter and a number of earlier models.

Bell System - A term which encompasses the American Telephone and Telegraph Company, its subsidiaries and associated operating companies, including Western Electric and the Bell Telephone Laboratories.

CRT Device - A terminal device which uses a Cathode ray tube as a screen on which information may be displayed. The unit may or may not include a keyboard. Also known as a keyboard display device or a video data terminal.

Dataphone - A trade mark and service mark of the Bell System which describes a tariffed data transmission service using the switched telephone network ("dial-up"), and the data sets that are used for that service. Dataphone is not a leased (dedicated) line service.

Dataspeed - A trade mark and service mark of the Bell System which describes a tariffed paper tape transmission service, including the transmitting and receiving equipment. Paper tape in any level from 5 to 8 is transmitted over voice grade lines, either dedicated or switched network.

EIA RS232 B - An Electronic Industries Association specification which specifies a standard interface between Data Terminal Equipment and Data Communications Equipment. Also known as a voltage interface. The standard defines a means of exchanging control signals and binary serialized data signals between data processing terminal equipment and data communications equipment.

FCC - The Federal Communications Commission, an independent federal agency which regulates radio, television, telephone, telegraph and other transmissions by wire and radio. Interstate services and foreign facilities originating in the United States are under the jurisdiction of the FCC whose powers are defined in the Communications Act (1934).

Interface - A common boundary or piece of equipment between two devices.

Inquiry-Response - Requests for information are transmitted from a remote terminal to a central processor where a response is generated and transmitted back to the terminal. The inquiry processing function may be combined with on-line updating.

INFOCOM - A store-and-forward message switching service provided by Western Union. Shared computers are located on Western Union premises, and the teletypewriter terminals and line facilities are furnished by Western Union.

Leased (dedicated) Line - Denotes the channel and channel equipment leased to a customer for his exclusive use, without inter-exchange switching arrangements. Also called private line.

Multiplexing - The division of a transmission facility into two or more channels by separating them in either frequency or time.

Multiplexor - A device which allows the concentration of several low speed data transmission channels into one higher speed channel by either time division or frequency division techniques.

Message Switching - The technique of receiving messages at a switching center, storing them until the proper outgoing line is available, and then retransmitting. Either a computer system or certain types of paper tape equipment can act as the store and forward element. No direct connection between the incoming and outgoing lines is set up as in line switching.

Modem - A contraction of "modulator-demodulator". A device that converts digital signals from a compute remote terminal or other business machine to analog type signals for compatibility with the telephone network, and does the reverse process at the receiving end of the circuit. In telephone company terminology, a modem is a data set.

Remote Batch Processing (Remote Job Entry) - Refers to computer programs or data being entered into a remote terminal for transmission to the central processor. Jobs can be "batched" before transmission.

Switched network - A nationwide complex of telephone channels and switching equipment that automatically routes information between the calling and called persons or data equipment, after dialing has been completed. Also known as the message or DDD network.

Synchronous System - A system in which the sending and receiving instruments are operating continuously at substantially the same frequency and are maintained by means of correction, if necessary, in a desired phase relationship.

Terminal - The device which is connected to the remote end of the communications line (relative to the computer), in an information system. Terminals include CRT devices, keyboard devices, paper tape devices, hard copy devices, punched card devices, magnetic tape devices and computer systems.

Telex - A dial-up message teletypewriter service with charges based on time and distance. Uses Baudot-coded, 5 level teletypewriter equipment.

TWX - Teletypewriter Exchange Service. A dial-up message teletypewriter service with charges based on time and distance. Two types of equipment are used - 5 level Baudot-coded teletypewriters operating at 60 words per minute, and 8 level ASCII-coded machines operating at 100 words per minute. TWX service has been provided by the Bell System Companies and competed with Western Union's Telex service. It is now (1970) being sold to Western Union.

TELPAK - A form of Bell System private line service which offers economies for the user of large numbers of circuits. At present, only TELPAK C and D are available which correspond to 60 or 240 equivalent voice grade channels. TELPAK can provide broadband (wideband) service for high speed data, or it can be subdivided for channels such as voice, teletypewriter, signaling, telemetering and low speed data.

WATS - Wide Area Telephone Service. A telephone company service which permits a user to make calls (on a dial basis), to telephone numbers (which may be data sets), in a specific zone, for a flat monthly rate. The U.S. is divided into zones and charges are based on the size of the zones. Service is available on a measured-time or a full time basis.